



US006036226A

United States Patent [19]

Brown et al.

[11] Patent Number: 6,036,226

[45] Date of Patent: Mar. 14, 2000

[54] INFLATOR CAPABLE OF MODULATION
AIR BAG INFLATION RATE IN A VEHICLE
OCCUPANT RESTRAINT APPARATUS[75] Inventors: Steven Joseph Brown, Pittsfield,
Mass.; Larry Stefan Ingram,
Lawrenceville, N.J.; Neale Arthur
Messina, Philadelphia, Pa.; Marek
Tarczynski, Princeton, N.J.[73] Assignee: General Dynamics Armament
Systems, Inc., Falls Church, Va.

[21] Appl. No.: 08/995,419

[22] Filed: Dec. 19, 1997

Related U.S. Application Data

[60] Provisional application No. 60/037,234, Feb. 3, 1997.

[51] Int. Cl.⁷ B60R 21/26

[52] U.S. Cl. 280/736; 280/742; 280/741

[58] Field of Search 280/741, 737,
280/742, 736

[56] References Cited

U.S. PATENT DOCUMENTS

4,341,147	7/1982	Mayer	89/7
4,523,507	6/1985	Magoon	89/7
4,523,508	6/1985	Mayer et al.	89/7
4,693,165	9/1987	Magoon et al.	89/7
4,745,841	5/1988	Magoon et al.	89/7
4,907,486	3/1990	Mayer	89/7
5,060,973	10/1991	Giovanetti	
5,284,330	2/1994	Carlson et al.	
5,414,845	5/1995	Brede et al.	
5,487,561	1/1996	Mandzy et al.	
5,639,117	6/1997	Mandzy et al.	280/741
5,669,631	9/1997	Johnson et al.	
5,683,104	11/1997	Smith	280/736

5,695,216	12/1997	Sandstrom et al.	
5,713,596	2/1998	Messina et al.	280/37
5,719,351	2/1998	Johnson et al.	
5,806,884	9/1998	Johnson et al.	280/736
5,829,784	11/1998	Brown et al.	280/737
5,857,699	1/1999	Rink et al.	280/737
5,907,120	5/1999	Mooney et al.	102/521
5,927,753	7/1999	Faigle et al.	280/735
5,941,040	9/1999	McFarland et al.	280/736
5,947,514	9/1999	Keller et al.	280/742
5,967,550	10/1999	Shirk et al.	280/736
5,970,880	10/1999	Perotto	102/531

OTHER PUBLICATIONS

Article entitled *faults and failures*, IEEE Spectrum Magazine, p. 17, May 1997.

Primary Examiner—Lanna Mai

Assistant Examiner—Andrew J. Ririe

Attorney, Agent, or Firm—Finnegan, Henderson, Farabow,
Garrett & Dunner

[57] ABSTRACT

In an occupant restraint apparatus for installation in a vehicle, a smart airbag inflator is provided with a piston for regeneratively pumping liquid propellant from a reservoir into a combustion chamber for ignition and combustion to generate airbag inflation gases. To control the airbag inflation rate, the piston includes a piston head slidably received in a damping chamber filled with a magneto-rheological fluid that is pumped through an orifice during the regenerative pumping stroke of the piston. An electromagnet is selectively energized to produce a varying magnetic field to adjust the viscosity of the magneto-rheological fluid flowing through the orifice and thus vary a damping force exerted on the piston stroke, thereby modulating the rate of liquid propellant combustion. Electromagnet current excitation is controlled in response to a particular accident scenario.

38 Claims, 2 Drawing Sheets

